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Sympathoadrenal balance and physiological stress response in cattle at spontaneous and $PGF_{2\alpha}$-induced calving

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ABSTRACT

Increased cortisol release in parturient cows may either represent a stress response or is part of the endocrine changes that initiate calving. Acute stress elicits an increase in heart rate and decrease in heart rate variability (HRV). Therefore, we analyzed cortisol concentration, heart rate and HRV variables standard deviation of beat-to-beat interval (SDRR) and root mean square of successive beat-to-beat intervals (RMSSD) in dairy cows allowed to calve spontaneously (SPON, $n = 6$) or with $PGF_{2\alpha}$-induced preterm parturition (PG, $n = 6$). We hypothesized that calving is a stressor, but induced parturition is less stressful than term calving. Saliva collection for cortisol analysis and electrocardiogram recordings for heart rate and HRV analysis were performed from 32 hours before to 18.3 ± 0.7 hours after delivery. Cortisol concentration increased in SPON and PG cows, peaked 15 minutes after delivery ($P < 0.001$) but was higher in SPON versus PG cows ($P < 0.001$) during and within 2 hours after calving. Heart rate peaked during the expulsive phase of labor and was higher in SPON than in PG cows (time $\times$ group $P < 0.01$). The standard deviation of beat-to-beat interval and RMSSD peaked at the end of the expulsive phase of labor ($P < 0.001$), indicating high vagal activity. Standard deviation of beat-to-beat interval ($P < 0.01$) and RMSSD ($P < 0.05$) were higher in SPON versus PG cows. Based on physiological stress parameters, calving is perceived as stressful but expulsion of the calf is associated with a transiently increased vagal tone which may enhance uterine contractility.

1. Introduction

Parturition is often assumed to be one of the most stressful events in life. In cattle, the expulsive stage of labor is markedly longer than in other domestic animals [1]. Therefore, even physiological calving may be more stressful than parturition in other monotocous animal species [2]. Whereas birth and immediate adaptation to the extrauterine environment evoke a distinct stress response in calves [3,4], less information is available in cows with undisturbed calving. Although cortisol release starts to increase before parturition and reaches a maximum during or shortly after expulsion of the calf [5,6], it is not clear to what extent this increase represents a stress response or is part of the maternal endocrine changes that initiate calving [6]. Cortisol release is higher in cows with dystocia compared to physiological calving [7], indicating that at least part of this release is stress-induced. In cattle as in other species, non–protein-bound cortisol rapidly diffuses from blood into saliva. Thus, salivary cortisol concentration

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reflects changes of free cortisol in blood plasma [8] and has been used to assess the response of cattle to potentially stressful situations [9]. It is generally assumed that changes in physiological stress parameters are closely correlated with pain experienced by the animal [6,9]. To minimize stress and, by inference, pain during labor, a liberal use of non-steroidal anti-inflammatory drugs in parturient cattle has recently been recommended for not only medical but also animal welfare reasons [10].

Besides stimulating cortisol release, acute stress and any physical demand elicit an immediate release of epinephrine and subsequent increase in heart rate. In addition to changes in cortisol and heart rate, heart rate variability (HRV), i.e. short-term fluctuations in heart rate, is used as an indicator for the autonomic nervous system response to stress. The HRV is essentially based on the antagonistic oscillatory influence of the sympathetic and parasympathetic (vagal) branch of the autonomous nervous system on the sinus node of the heart. It thus reflects the prevailing balance of sympathetic and vagal tone. In general, increases in the values of the HRV variables standard deviation of beat-to-beat interval (SDRR) and root mean square of successive beat-to-beat differences (RMSSD) reflect a shift toward parasympathetic dominance, whereas reduced values indicate a shift toward sympathetic dominance [11]. Heart rate variability has been used to assess the stress response of cattle to veterinary interventions such as castration [9] or transrectal palpation [12], during pregnancy [13] and at physiological calving [14]. Rectal palpation caused a decrease in HRV, which was interpreted as a stress reponse [12], whereas in pregnant cows, HRV decreased during the last months before calving [13].

To avoid birth of oversized calves, improve monitoring of parturition, and ensure timely obstetrical intervention in case of dystocia, calving can be induced with prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) or its analogues. Induction of parturition up to 2 weeks before the physiological end of gestation does not endanger neonatal calf viability [15].

To what extent the maternal stress response differs between preterm and term calving to the best of our knowledge has not been investigated so far. Therefore, we have analyzed for the first time combined changes in salivary cortisol concentration, heart rate, and HRV variables SDRR and RMSSD in peripartum cows. Animals were either allowed to calve spontaneously or parturition was induced with a $PGF_{2\alpha}$ analogue on Day 278 of gestation to obtain calves with different weight at birth. We hypothesized that calving is a stressor for cows and, by inference, experienced as painful. We assumed that preterm-induced parturition is less stressful than calving at term due to a lower birth weight of the calf.

2. Materials and methods

2.1. Animals

A total of 18 pluriparous Austrian dairy and/or dual purpose Simmental cows housed at the Research and Teaching Farm of the Vetmeduni Vienna were available for this study. Two cows with dystocia (requiring Caesarean section and extraction of the calf, respectively), 1 cow with the calf in posterior presentation and 1 cow that delivered twins were excluded. In addition, two cows had to be excluded because no clear electrocardiogram (ECG) signal could be obtained during calving. Eventually, 12 cows allocated to two groups were included into the final analysis of this study. These carried singleton pregnancies, were healthy throughout gestation and did not require veterinary intervention at calving. Animals were housed in groups in a freestall barn. Cows were milked twice daily and dried off 8 weeks before the expected day of calving. Average milk yield in the herd was 8900 kg per 305 days of lactation. Cows were fed according to their requirements for maintenance and production with high-quality roughage (maize silage, grass silage, hay) and concentrates. Minerals and water were freely available at all times. Cows were separated in a maternity pen when approaching parturition and remained there until the end of the observation period 1 day after calving. Calves were removed from their dams immediately after birth.

2.2. Experimental design

Cows were either allowed to calve spontaneously (group SPON, $n = 6$) or calving was induced with a $PGF_{2\alpha}$ analogue (group PG, $n = 6$). For distribution to groups, cows were ranked by date of last artificial insemination and allocated in alternating order to groups SPON and PG. Gestational length in SPON cows was 287.2 ± 2.3 days. In PG cows, parturition was induced with the $PGF_{2\alpha}$ analogue cloprostenol (0.5 mg i.m., Estrumate; MSD Animal Health, Vienna, Austria) on Day 278 of gestation at 8:00 AM. In cows of group PG, parturition occurred on Day 279.5 ± 0.2 of gestation (33.6 ± 2.4 hours after $PGF_{2\alpha}$ injection). Length of gestation differed significantly between groups ($P < 0.01$), whereas groups did not differ with regard to parity (SPON 3.8 ± 0.7 and PG 3.7 ± 0.6) and age (SPON 68 ± 9 and PG 67 ± 9 months).

The experimental protocol included ECG recordings and frequent saliva collections in the last 32 hours before parturition, during the expulsive phase of labor (time from rupture of the fetal membranes to birth of the calf) and the first 2 hours thereafter. Saliva sampling and ECG recordings were started at 2 hours after injection of the $PGF_{2\alpha}$ analogue in group PG and when calving was considered to occur within 48 hours in group SPON.

The experiment was approved by the competent authority for animal experimentation in Austria (Federal Ministry for Science and Research, license number BMWF-68.205/0082-II/3b/2013).

2.3. Electrocardiography, heart rate, and heart rate variability analysis

The ECG measurements were obtained with the Televet 100 recording system (version 5.1.1, Engel Engineering, Heusenstamm, Germany) as described for fetomaternal ECGs in cattle [13] with modifications. Electrocardiogram settings were 50 mm/s feed and 30 mm/mV gain. The European standard color scheme for diagnostic ECG systems was used for identification of electrodes. The electrodes were fixed after shaving on the skin of the cow with